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ORIGINAL INVESTIGATION

Repeated High-Intensity Running and Sprinting in Elite Women's Soccer Competition

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Background: To the authors' knowledge, no study has investigated the concurrent repeated, high-intensity (RHIA) and repeated-sprint activity (RSA) of intermittent team-sport competition. ***Purpose:*** In this study, they report on the RSA of elite women's football competition. In addition, they describe the nature of RHIA (eg, striding and sprinting activities) that involve a high energy cost and are associated with short (ie, ≤20 s) recovery periods. ***Methods:*** Thirteen elite women soccer players underwent video-based time–motion analysis on 34 occasions during national and international standard matches. RSA and RHIA were defined as successive (ie, 2) sprints or striding and sprinting efforts that occurred with ≤20 s between efforts. ***Results:*** The number of RSA and RHIA bouts performed was similar between the first and second halves of matches. Sprinting and striding/sprinting durations tended to remain relatively stable irrespective of the number of efforts in an RSA or RHIA bout or the period of play. However, recovery duration between efforts increased in the second half, when a greater number of efforts were performed per bout. ***Conclusion:*** These findings suggest that first- to second-half reductions in RHIA and RSA do not occur in elite women's soccer competition. However, players increase the amount of low-intensity recovery undertaken between RHIA and RSA efforts, most likely in an attempt to maintain RHIA and RSA performance. These findings emphasize the importance of RSA and RHIA to elite women's soccer and highlight the importance of training this quality to prevent reductions in performance during competitive match play.

Keywords: time-motion analysis, high-speed running, repeated-sprint ability, training, team sports

Repeated-sprint and prolonged high-intensity running ability are widely accepted as critical components of high-intensity intermittent team sports (eg, soccer). In soccer competition it has been shown that periods of fatigue follow the most intense bouts of high-intensity running.[1] Reports on the relative importance of high-intensity running to elite male and female soccer performance are equivocal, with some[2,3] but not all[4,5] studies demonstrating that elite players perform more high-intensity running than subelite competitors and when the demands of competition are greatest. The number and intensity of repeated-sprint bouts have also been reported to be a significant discriminator of elite and subelite female soccer competition.[6] In a study of female soccer players, Gabbett and Mulvey[6] demonstrated that players performed, on average, more repeated-sprint bouts in international matches (4.8 bouts/match) than national (1.0 bout/match) and domestic (1.4 bouts/match) matches. The average number of sprints was greater, and recovery between sprints shorter, in international competition. Collectively, these results suggest that repeated-sprint activity and the amount of high-intensity running performed may differ according to competitive standard.

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Despite the importance of high-intensity running[1,2] and repeated-sprint ability[6–8] to competitive success in high-intensity intermittent team sports, studies investigating the nature of repeated high-intensity activity in these sports are limited.[9–12] Spencer et al[7] subjectively assessed the sprint and repeated-sprint demands of elite field hockey using video time–motion analysis. They reported that repeated-sprint bouts (defined as a minimum of 3 sprints with ≤20 s recovery between sprints) occurred on 17 occasions throughout the match. The average number of sprints within the repeated-sprint bouts was 4 (± 1), with a mean recovery time of 14.9 seconds between sprint efforts. It has been suggested that while repeated sprints occur infrequently, the ability or inability to perform these activities may prove critical to the outcome of a match,[7] although to date, there is limited evidence to support this claim.[8]

Although repeated-sprint activity provides an indication of the most demanding passages experienced during match play, operational definitions of repeated-sprint ability (ie, 3 or more sprints with ≤20 s recovery between sprints) may only provide a limited picture of the physically demanding running activities that occur in high-intensity, intermittent team sports. For example, repeated-sprint bouts may include a range of sprint-effort frequencies, with relatively long or short recovery between efforts; reporting the average demands alone may underestimate the most extreme demands that might

be expected during competition. In addition, limiting repeated-sprint bouts to 3 or more sprints effectively eliminates successive, short-recovery sprints that may also be physically demanding but fail to meet the traditional repeated-sprint criteria.[7] Equally, high-speed running (ie, striding) efforts, which may also be separated by short recovery periods, are likely to make a substantial contribution to the energy cost of competition, despite failing to qualify as repeated-sprint activity. An understanding of these repeated, high-intensity activity bouts would provide strength and conditioning coaches with evidence to inform conditioning programs to adequately prepare players for the repeated high-intensity (both striding and sprinting) demands of competition.

To our knowledge, no study has investigated the concurrent, repeated, high-intensity activity (ie, striding and sprinting) and repeated-sprint demands of intermittent team-sport competition. In this study, we report on the repeated-sprint demands of elite women's soccer competition, with special reference to the number of sprints within a bout and the typical sprint and recovery durations within these high-intensity activities. In addition, we describe the nature of repeated high-intensity activities (eg, striding and sprinting) that involve a high energy cost and are associated with short (ie, ≤20 seconds) recovery periods, to document repeated high- and very-high-intensity exercise bouts in this sport.

Methods

Subjects

Thirteen elite women soccer players (mean ± SD age, 21 ± 2 y) participated in this study. Athletes were scholarship holders with the Queensland Academy of Sport women's soccer program and/or members of the Australian Matildas women's soccer team. All participants received a clear explanation of the study, including the risks and benefits of participation, and written consent was obtained. The institutional review board for human investigation approved all experimental procedures.

Time–Motion Analysis

Video-based time–motion analysis was performed during 10 national and 5 international standard competitive matches. Players were filmed and analyzed on 34 occasions (19 national and 15 international player appearances) over the course of the 15 matches. The mean ± SD number of national and international matches analyzed per player was 2.7 ± 1.1 and 2.1 ± 1.5, respectively. All matches were 90 minutes in duration and played on a full-size pitch (100 × 65 m). Only outfield players (ie, strikers, midfielders, and defenders) were filmed. No substitutes were filmed or analyzed in this study. All comparisons between the first and second halves were made on the same player. Video recordings were made using digital video cameras (Sony, DCR-TRV 950E). Cameras were positioned in the stadium on the halfway line, approximately 30 m above the field of play, to cover the entire playing arena. The zoom function of the video camera was used during recording so that the image of the player and a 10-m radius of her surrounds was maintained. Up to 4 cameras were used in any given match, and players had no knowledge of who was being filmed for each match.

The video recordings were analyzed by an experienced observer by logging frequency and duration of the activities performed using purpose-built software (Gab-Trakka, Brisbane, Australia). A description of all match-play activities is provided in Table 1. The initiation and completion of each individual activity were recorded, and the duration of each activity was calculated. The time spent standing, walking, and jogging was considered low-intensity exercise, with striding and sprinting regarded as high-intensity exercise. The typical errors of measurement (% coefficient of variation, CV) for test–retest reliability for the activities of standing, walking, jogging, striding, and sprinting were 0.6%, 0.3%, 2.4%, 4.6%, and 3.5%, respectively.

Repeated-Sprint and Repeated High-Intensity Activity

Repeated-sprint activity (RSA) was defined in 2 ways. First, it was defined as a minimum of 3 sprints, with ≤20 seconds between sprints.[7] The mean, maximal, and minimal duration of sprints; number of sprint repetitions; and recovery duration were also recorded. To account for physically demanding repeated sprints that did not meet the traditional repeated-sprint definition, we also recorded successive (ie, 2) sprints that occurred with ≤20 seconds between sprints. We also adapted this definition to record the frequency of repeated high-intensity activity (RHIA, ie, a combination of striding and/or sprinting) bouts. RHIA was defined as a minimum of 2 consecutive sprints or striding efforts with ≤20 seconds between efforts.

Table 1 Match-Play Activities Used During Time-Motion Analysis of Women Soccer Players

Match-play activity	Definition
Standing	No locomotor activity
Walking	Movement involves at least 1 foot being in continual contact with the ground
Jogging	Movement involves a flight phase and minimal arm swing
Striding	Movement is similar to jogging but involves a longer stride and more pronounced arm swing
Sprinting	Maximal effort with a greater extension of the lower leg during forward swing and higher heel lift relative to striding

Statistical Analysis

Differences in RSA and RHIA (striding and/or sprinting) demands between the first and second halves of matches were analyzed using a practical approach based on the real-world relevance of the results.[13] Differences in the RSA and RHIA demands between the first and second halves of matches and national and international competition were analyzed using Cohen's effect size (ES) statistic and 90% confidence limits. ESs of <0.2, 0.2 to 0.6, 0.6 to 1.2, 1.2 to 2.0, and >2.0 were considered trivial, small, moderate, large, and very large, respectively.[13] Given our small sample size and that a wide between-matches variability has been shown for the amount of high-speed running and sprinting performed in soccer,[14] a moderate ES was chosen as our lower limit for observed differences. All data are reported as mean ± SD.

Results

The number of repeated-sprint and striding actions per bout when analyzed as sets of 2, 3, 4, 5, or 6 efforts is shown in Table 2. In general, there was wide variability in the number of RSA bouts performed among the different players, with 5.1 ± 5.1 (range 0–23) RSA bouts performed per player per match. Sprint bouts consisting of successive sprints (ie, 2 sprint efforts) were the most common type of RSA bout. Some players (n = 6, 17.7%) performed no repeated-sprint bouts, and others performed up to 23 in a match. The greatest number of sprints in any single bout was 7. The average sprint duration throughout the various RSA bouts was 2.17 ± 0.13 seconds, with sprint duration remaining relatively stable across short (ie, 2 sprints; 2.27 ± 0.56 s) and long (ie, 6 sprints; 2.08 ± 0.19 s) RSA bouts. However, the mean recovery duration progressively increased with a greater number of sprints per bout.

RHIA bouts that included a combination of striding and/or sprinting were more common than RSA bouts; players performed on average 31.2 ± 18.7 RHIA bouts per game. The most common type of RHIA bout involved 2 efforts. Repeated striding and sprinting activities that involved 6 efforts occurred on 11.1 ± 13.8 occasions per player per game. The average stride and sprint duration throughout the

Table 2 Number of Repeated-Sprint and Repeated High-Intensity Activity (ie, Sprinting and/or Striding) Efforts per Bout When Analyzed as Sets of 2, 3, 4, 5, or 6 Efforts, With the Recovery Criteria Being ≤20 s Between Efforts, Mean ± SD

Actions per bout	2	3	4	5	6
Sprint					
National players					
n per player per game	5.3 ± 5.0	2.6 ± 2.8	1.2 ± 1.8	0.4 ± 0.8	0.1 ± 0.3
sprint duration (s)	2.21 ± 0.57	2.03 ± 0.49	2.30 ± 0.83	1.96 ± 0.52	1.83 ± 0.24¶
recovery duration (s)	9.73 ± 4.93	13.64 ± 4.29	14.60 ± 4.18¥	14.56 ± 2.22	15.92 ± 2.47
International players					
n per player per game	4.9 ± 5.4	2.5 ± 3.4	1.1 ± 2.3	0.6 ± 1.6	0.4 ± 1.1
sprint duration (s)	2.35 ± 0.56	2.32 ± 0.66	2.12 ± 0.48	1.94 ± 0.56	2.32 ± 0.15
recovery duration (s)	10.22 ± 4.42	11.93 ± 4.67	11.97 ± 4.09	15.36 ± 5.99	17.22 ± 2.50
All matches					
n per player per game	5.1 ± 5.1	2.5 ± 3.0*	1.1 ± 2.0*	0.5 ± 1.2†‡	0.2 ± 0.7†‡
sprint duration (s)	2.27 ± 0.56	2.16 ± 0.60	2.24 ± 0.77	1.96 ± 0.51	2.08 ± 0.19
recovery duration (s)	9.94 ± 4.73	12.95 ± 4.34*	13.28 ± 3.99*	15.11 ± 3.74†	16.57 ± 2.49†‡§
Sprint/Stride					
National players					
n per player per game	34.4 ± 19.2	24.0 ± 16.9	19.5 ± 17.0	14.9 ± 14.1	12.0 ± 13.1
sprint/stride duration (s)	3.05 ± 0.76	3.02 ± 0.84	3.05 ± 0.86	2.86 ± 0.75	2.96 ± 0.77
recovery duration (s)	9.55 ± 2.58	11.34 ± 2.99	12.78 ± 3.04	13.96 ± 2.76	14.76 ± 2.49
International players					
n per player per game	27.3 ± 17.9	20.0 ± 16.1	14.8 ± 15.9	12.1 ± 15.0	9.9 ± 15.1
sprint/stride duration (s)	2.98 ± 0.66	2.94 ± 0.72	2.98 ± 0.76	2.87 ± 0.65	2.93 ± 0.67
recovery duration (s)	9.42 ± 2.68	12.55 ± 3.08	13.72 ± 3.38	14.66 ± 3.16	14.70 ± 3.18
All matches					
n per player per game	31.2 ± 18.7	22.2 ± 16.4*	17.4 ± 16.4*	13.7 ± 14.4*	11.1 ± 13.8†‡
sprint/stride duration (s)	2.98 ± 0.66	2.94 ± 0.72	2.98 ± 0.76	2.87 ± 0.65	2.93 ± 0.67
recovery duration (s)	9.49 ± 2.60	11.86 ± 3.07*	13.21 ± 3.17†	14.23 ± 2.90†‡	14.74 ± 2.66†‡

*Moderate effect size (0.6–1.2) between bouts of 2 and subsequent bouts. †Large effect size (1.2–2.0) between bouts of 2 and subsequent bouts. ‡Moderate effect size (0.6–1.2) between bouts of 3 and subsequent bouts. §Moderate effect size (0.6–1.2) between bouts of 4 and subsequent bouts. ¥Moderate effect size (0.6–1.2) between national and international players. ¶Very large effect size (>2.0) between national and international players.

various RHIA exercise bouts was 2.94 ± 0.05 seconds, with sprinting and striding durations remaining relatively stable across short (ie, 2 sprint/stride efforts; 2.98 ± 0.66 s) and long (ie, 6 sprint/stride efforts; 2.93 ± 0.67 s) RHIA exercise bouts. Consistent with RSA bouts, the mean recovery duration between sprinting and striding efforts progressively increased with a greater number of efforts per bout.

When analyzed as sets of 6 efforts, the average sprint duration in RSA bouts of international matches was greater (26.0% ± 24.2%, ES = 2.48) than in national matches. No other meaningful differences (ES = 0.03–0.50) were found between national and international matches for average sprint duration in RSA bouts. No meaningful differences (ES = 0.08–0.29) were detected between national and international matches for the average effort duration of RHIA bouts.

The recovery duration of sets of 4 RSA bouts was moderately shorter (22.0% ± 20.3%, ES = 0.64) in international than national matches. However, only trivial to small differences (ES = 0.02–0.40) were observed between national and international matches for recovery durations between sprinting/striding efforts in RHIA exercise bouts.

While the small sample size limited our analysis of positional differences, the number of RSA bouts performed was generally higher in central midfielders (7.4 ± 4.5 national, n = 5; 10.0 ± 11.3 international, n = 3) than wide midfielders (1.0 ± 1.0 national, n = 3; 6 international, n = 1), strikers (6.0 ± 6.7 national, n = 5; 3.6 ± 2.3 international, n = 5), and defenders (5.3 ± 4.4 national, n = 6; 3.2 ± 2.3 international, n = 6). The number of RHIA bouts performed was also generally higher in central midfielders (37.8 ± 19.7 national, n = 5; 39.7 ± 35.2 international, n = 3) than wide midfielders (24.7 ± 9.1 national, n = 3; 6 international, n = 1), strikers (42.2 ± 20.6 national, n = 5; 26.8 ± 9.2 international, n = 5), and defenders (32.1 ± 21.1 national, n = 6; 20.7 ± 13.6 international, n = 6).

Possibly small differences (confidence limits 30% ± 31%, ES = 0.29) were found between the first and second halves of matches for the number of RSA (3.0 ± 3.2 vs 2.1 ± 2.8) bouts performed. In addition, there was a possibly small decrease (14% ± 11%, ES = 0.22) in the number of RHIA bouts from the first (16.8 ± 11.3) to the second half (14.4 ± 10.0) of matches. In general, there was a greater frequency of RSA and RHIA bouts in the first 15 minutes of the match, with the frequency of RSA and RHIA bouts declining over the course of the match for both national and international players (Figure 1).

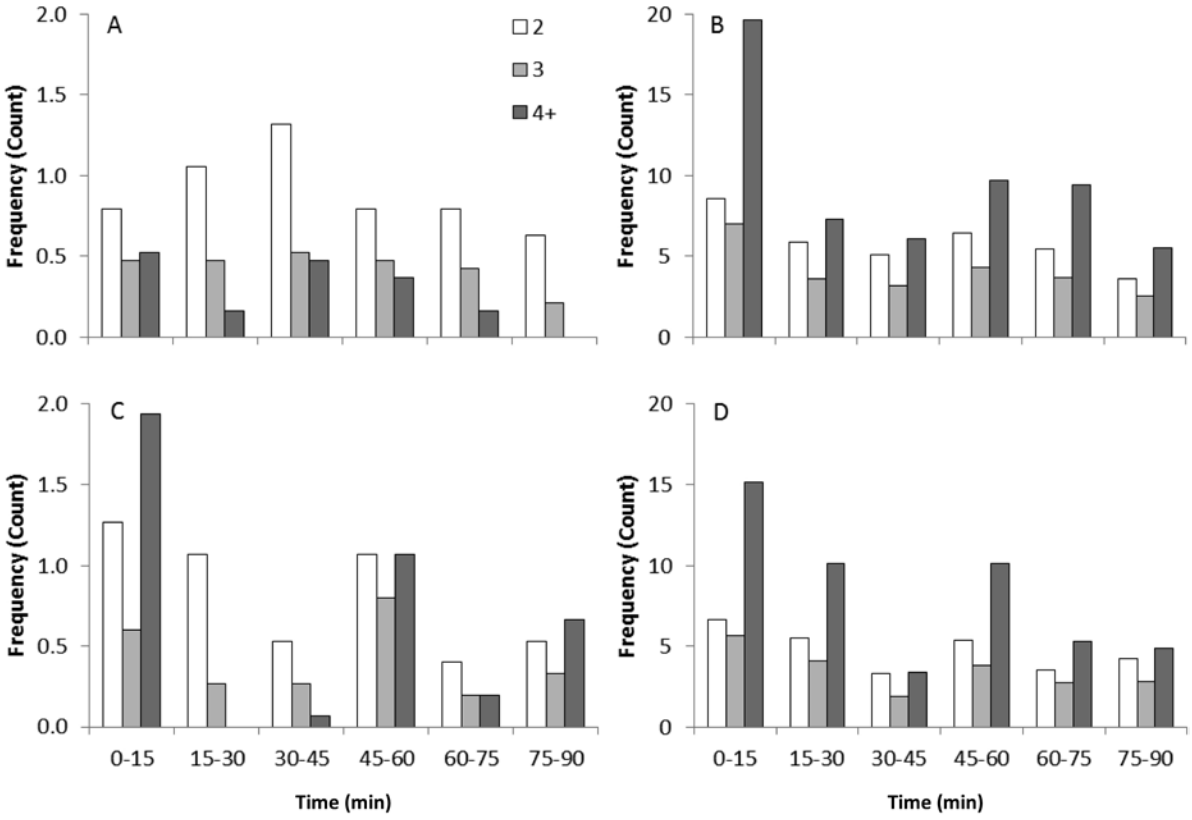

Figure 1 — Number of bouts of repeated-sprint activity (RSA) and repeated high-intensity activity (RHIA, ie, sprinting and/or striding) when analyzed as sets of 2, 3, or 4+ efforts in 15-min periods throughout the game for national and international players. (A) RSA for national players. (B) RHIA for national players. (C) RSA for international players. (D) RHIA for international players. Data are presented as the mean number of RSA and RHIA bouts performed in each 15-min period of the match.

After the halftime break, there was a trend toward more RSA and RHIA bouts during the 45- to 60-minute period compared with the 2 previous and subsequent periods.

Figure 2 shows the first- and second-half recovery durations per RSA and RHIA bout, when analyzed as sets of 2, 3, 4, 5, or 6 efforts. RSA bouts were associated with very likely greater recovery durations between efforts for sets of 4 (22.3% ± 18.5%, ES = 0.67) and 5 (26.2% ± 5.7%, ES = 0.93) sprints in the second half compared with the first half of matches. Approximately 88% to 90% of motion involved low-intensity activity. The time spent standing (5.4% vs 8.5%), walking (36.5% vs 30.4%), jogging (47.6% vs 49.8%), and striding (10.4% vs 11.3%) between RSA bouts changed differentially from the first to the second half. Only trivial to small differences (ES = 0.01–0.33) were observed between the first and second halves of matches for recovery durations between sprinting/striding efforts in RHIA exercise bouts. The percentage of time spent standing, walking, and jogging between RHIA bouts in the first and second halves was 7.0% and 7.2%, 39.4% and 44.6%, and 53.6% and 48.2%, respectively.

Figure 3 shows the percentage change in recovery duration between RSA bouts and RHIA bouts, expressed relative to sets of 2 RSA or RHIA exercise bouts. Moderate (ES = 0.6–1.2) to large (ES = 1.2–2.0) increases in recovery durations were observed for both RSA and RHIA bouts as the number of efforts in the respective bouts increased. In comparison with RHIA bouts, larger recovery durations were observed in RSA bouts when sprint activity increased to 6 efforts per bout (11.4% ± 6.8%, ES = 1.2).

Figure 4 shows the percentage change in recovery duration between RSA bouts and RHIA bouts for national and international matches, expressed relative to sets of 2 RSA or RHIA exercise bouts. Very large differences in recovery durations between national and international matches were observed for RSA bouts involving 3 (23.5% ± 3.8%, ES = 2.33) and 4 (32.9% ± 5.8%, ES = 3.01) efforts, with national matches associated with greater recovery durations than international matches. Conversely, the recovery duration between RHIA efforts for international matches was greater than for national matches for RHIA bouts involving 3 (14.5% ± 5.0%, ES = 2.15), 4 (11.8% ± 1.4%, ES = 1.21) and 5 (11.2% ± 1.7%, ES = 0.89) efforts.

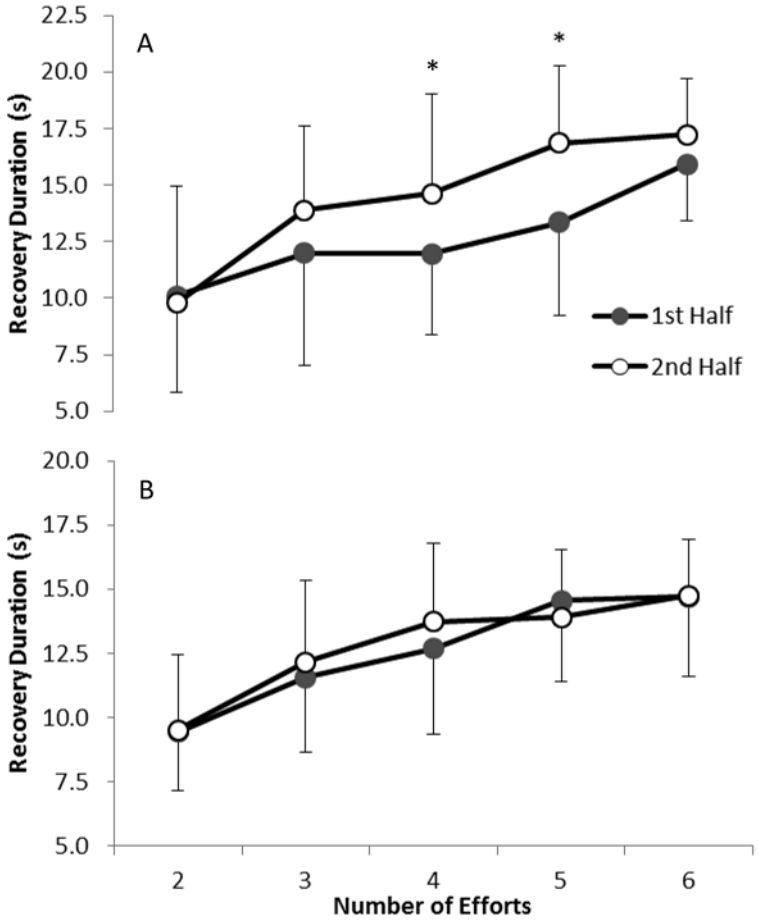

Figure 2 — Comparison of first- and second-half recovery durations per bout for (A) repeated-sprint and (B) repeated high-intensity activity (ie, striding and/or sprinting), when analyzed as sets of 2, 3, 4, 5, or 6 efforts, with the recovery criteria being ≤20 s between efforts. Data are mean ± SD. *Moderate effect size (0.6–1.2).

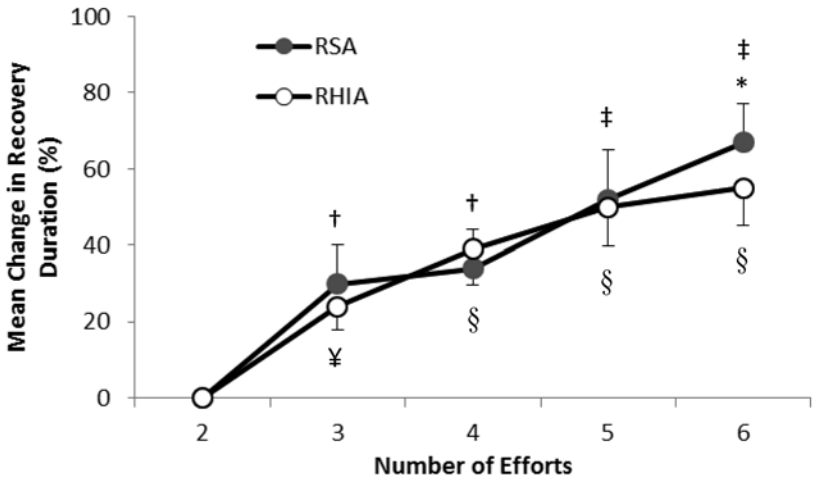

Figure 3 — Comparison of mean recovery duration between bouts of repeated-sprint (RSA) and repeated high-intensity activity (RHIA, ie, striding and/or sprinting) when analyzed as sets of 2, 3, 4, 5, or 6 efforts, with the recovery criteria being ≤20 s between efforts. Data are presented as percentage change from sets of 2 bouts (mean ± SD). *Moderate effect size (0.6–1.2) between RSA and RHIA (ie, striding and/or sprinting); †Moderate and ‡large effect size (1.2–2.0) between bout 2 and subsequent bouts for RSA; ¥Moderate and §large effect size between bout 2 and subsequent bouts for RHIA (ie, striding and/or sprinting).

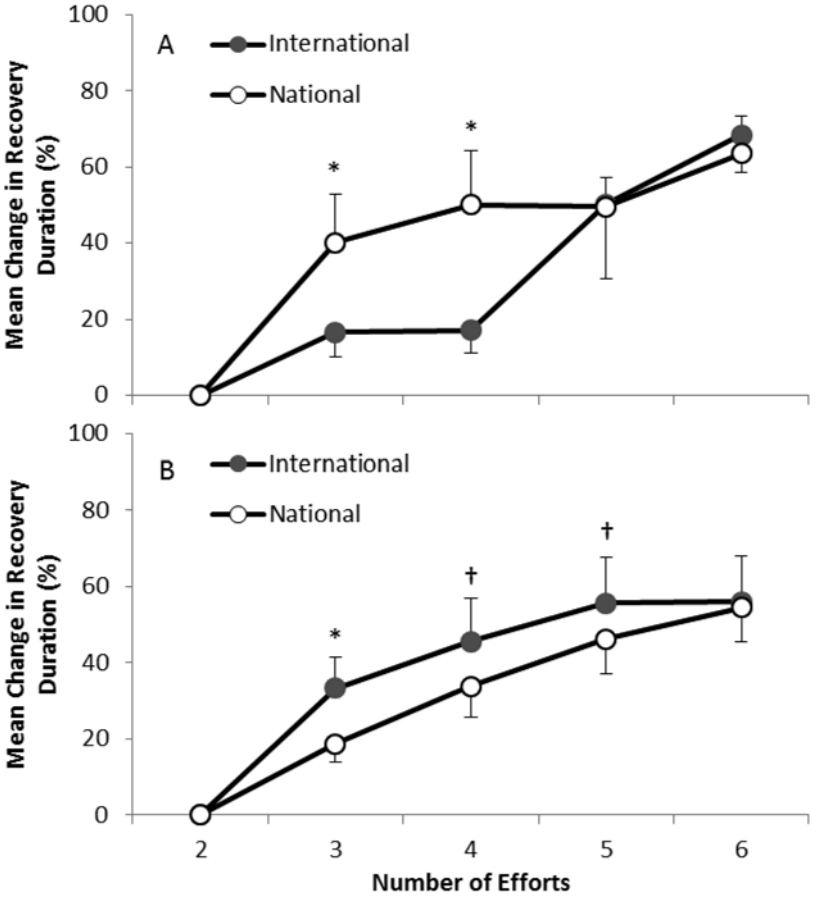

Figure 4 — Comparison of mean recovery duration for national and international players between bouts of (A) repeated-sprint and (B) repeated high-intensity activity (ie, striding and/or sprinting) when analyzed as sets of 2, 3, 4, 5, or 6 efforts, with the recovery criteria being ≤20 s between efforts. Data are presented as percentage change from sets of 2 bouts (mean ± SD). *Very large effect size (>2.0) between groups; †Large effect size (1.2–2.0) between groups.

Discussion

This study investigated the repeated-sprinting and high-intensity exercise (eg, striding and sprinting) demands of elite women's soccer match play. The numbers of repeated-sprint and repeated high-intensity exercise (ie, striding and sprinting) bouts performed were similar between the first and second halves of matches. While sprint duration tended to remain relatively stable irrespective of the number of sprints in a repeated-sprint bout or the period of play (ie, first or second half), recovery between sprints increased in the second halves of matches and when more efforts were performed per bout. These findings suggest that first- to second-half reductions in repeated high-intensity exercise activity and repeated-sprint activity do not occur in elite women's soccer competition. However, players increase the amount of low-intensity recovery undertaken between repeated high-intensity exercise and repeated-sprint efforts, most likely in an attempt to maintain repeated high-intensity activity and repeated-sprint performance.

The results of this study demonstrate large individual variations in the repeated-sprint demands of elite women's soccer match play, with some players performing no repeated-sprint bouts and others performing up to 23 repeated-sprint bouts in a match. While our sample size prevented a detailed analysis of the repeated-sprint and high-intensity activity demands of different playing positions, it is likely that this variability is explained by the different positional demands experienced in soccer.[5] The number of sprints also varied considerably, with as few as 2 sprints in a bout (53.5%) and as many as 7 sprints (0.6%) in a bout. The player with the single highest number of repeated-sprint bouts in a match performed 23 repeated-sprints bouts, of which 9 involved 4 sprints, 6 involved 5 sprints, 4 involved 6 sprints, and 2 bouts involved as many as 7 sprints. These findings highlight the stochastic nature of women's soccer while also emphasizing the highly variable nature of repeated-sprint activity in this sport. Clearly, conditioning programs designed to improve repeated-sprint ability should focus on bouts with varying sprint frequencies and recovery durations that mimic the intense, intermittent, and unplanned nature of sprinting in the sport. Moreover, individualized and position-specific conditioning programs may be necessary for some players to adequately prepare them for the large amounts of repeated-sprint and repeated high-intensity activity required in competition.

We found that the average number of repeated-sprint bouts and mean sprint duration was maintained across the duration of the match, although, consistent with previous studies of the high-intensity running demands of elite soccer,[1,3] the frequency of RSA and RHIA bouts in the first 15 minutes of the match tended to be higher than during other 15-minute periods. The finding of maintained repeated-sprint activity across the first and second halves of matches in the current study is consistent with the results from male soccer players, in whom sprinting performance was also maintained across the duration of a match, despite reductions in total distance covered and distances covered in high-speed running.[15] We also found that recovery duration progressively increased with increases in the number of efforts performed per bout. In addition, while mean sprint duration was relatively stable from the first to the second half of the match, recovery durations between sprint efforts were longer in the second half. It has previously been shown that points scored or conceded in elite team-sport competition occur in close proximity to a repeated-effort bout,[8] suggesting that the ability (or inability) to perform repeated-sprint activity may prove critical to the outcome of a match. It is unclear if the increase in recovery durations in the second half of matches, and with greater sprint frequencies, observed in the current study represents conscious control by players. However, these results may suggest a pacing strategy employed by players in an attempt to preserve repeated-sprint performance.[16]

A novel aspect of this study was the expansion of previous repeated-sprint definitions to include repeated high-intensity exercise (ie, striding and sprinting) activities and repeated successive (ie, 2) sprints. Previous studies have defined repeated-sprint activity as 3 or more sprints, with short (≤20 s) recovery between sprints.[7] While this definition has provided a consistent method of assessing repeated-sprint ability, limiting repeated-sprint bouts to 3 or more sprints effectively eliminates successive, short-recovery sprints that may also be physically demanding but fail to meet the traditional (ie, 3 or more sprints) repeated-sprint criteria. Equally, high-speed running (ie, striding) efforts, which may also be separated by short recovery periods, are likely to make a substantial contribution to the energy cost of competition, despite failing to qualify as repeated-sprint activity. Consistent with studies from other high-intensity intermittent team sports (eg, water polo),[10] the number of repeated high-intensity efforts increased considerably when considering repeated-sprint bouts that only included 2 sprints. Furthermore, the number of repeated-effort bouts performed per player increased from 5.1 to 31.2, when considering repeated striding and sprinting rather than repeated sprinting alone. However, rather than overemphasizing the repeated-sprint demands of competition, we believe these findings provide a more complete picture of the repeated high-intensity activity that is required in elite women's soccer match play. These findings provide specific information for the design of conditioning programs to meet the repeated high-intensity exercise (ie, striding and sprinting) demands of intermittent team sports. These findings consider activities that are physically demanding, including those that do not involve sprinting.

In general, few differences were observed between national and international matches for the durations of sprinting efforts (in RSA bouts), sprinting and striding efforts (in RHIA bouts), and recovery between efforts (for both RSA and RHIA bouts). However, the average sprint duration was longer in international matches (2.32 ± 0.15 s vs 1.83 ± 0.24 s) when RSA bouts consisted of 6 efforts, and the recovery duration between efforts was

shorter in international matches (11.97 ± 4.09 s vs 14.60 ± 4.18 s) when RSA bouts consisted of 4 efforts. Of interest was the percentage change in recovery duration between RSA and RHIA bouts for national and international matches when recovery durations were expressed relative to sets of 2 RSA and RHIA exercise bouts. RSA bouts involving 3 and 4 efforts were associated with greater recovery durations for national matches, while the recovery duration between RHIA efforts for international matches was greater than for national matches for RHIA bouts involving 3, 4, and 5 efforts. While previous studies have investigated the physical demands of soccer match play, reports on the relative importance of high-intensity running to soccer performance are equivocal, with some[2,3] but not all[4,5] studies demonstrating that elite players perform more high-intensity running than sub-elite competitors and when the demands of competition are greatest. Our results are generally consistent with the hypothesis that RSA demands are similar between national and international competition, although in international matches the absolute sprint durations are slightly longer and absolute recovery durations slightly shorter than in national matches. Furthermore, in comparison with national matches, elite female soccer players have higher relative recovery durations between RHIA efforts in international matches, perhaps due to the relatively short recovery durations between RSA efforts.

In this study, the physical demands of national and international women's soccer matches were assessed using video-based time–motion analysis. Due to the time-consuming and labor-intensive nature of this methodology, our sample size is limited. Consequently, while the RSA and RHIA demands tended to be greater in central midfielders, our ability to perform a comprehensive analysis and make definitive conclusions on the differences in RSA and RHIA among playing positions is restricted and could be viewed as a limitation of this study. While the use of global-positioning-system (GPS) technology would permit a much larger study to be performed, including a detailed analysis of positional differences, current restrictions applied by the International Federation of Association Football (FIFA) preventing players from wearing microsensor technology in competition may limit further progress in research in the field of repeated-sprint and repeated high-intensity exercise activity. In addition, while it has recently been shown that performance, physiological, and perceptual responses may be influenced by the magnitude of directional change during repeated-sprint bouts,[17] we made no attempt to quantify repeated change-of-direction activities. Although this decision may have resulted in an underestimation of the repeated-sprint and high-intensity exercise demands of women's soccer match play, we reconciled this decision with the knowledge that the coding of our other match-play activities was highly reproducible.

In conclusion, this study investigated the repeated-sprinting and high-intensity exercise (eg, striding and sprinting) demands of elite women's soccer match play. A major new finding of this study was the manner in which repeated-sprint and repeated high-intensity exercise (ie, striding and sprinting) activity changed across the duration of a competitive match. When comparing the repeated-sprint and repeated high-intensity exercise demands of the first and second halves, no differences were found for the number of repeated-sprint or repeated high-intensity exercise bouts performed. Furthermore, the recovery between repeated-sprint efforts increased from the first to the second half, while the recovery between repeated high-intensity exercise efforts remained relatively stable. These findings suggest that reductions in performance manifest in different ways for repeated-sprint and repeated high-intensity exercise ability. It appears that repeated-sprint activity is protected by decreasing the amount of repeated high-intensity exercise performed or by increasing the amount of low-intensity recovery activity undertaken between repeated sprints.

Practical Applications

This study described the unique repeated high-intensity exercise demands of elite women's soccer match play. Repeated-sprint bouts involved as few as 2 and as many as 7 sprint efforts. As the number of sprints performed per bout increased, the recovery durations between sprints also increased. Despite the intense nature of the repeated-sprint and repeated high-intensity exercise bouts, players were able to maintain repeated-effort performance over the duration of the match. These findings can be used by coaches to adequately prepare players for the repeated high-intensity (both striding and sprinting) demands of competition. Critically, these results emphasize the importance of repeated-sprint and effort ability to elite women's soccer and highlight the importance of training this quality to prevent reductions in performance during competitive match play.

References

1. Mohr M, Krustrup P, Bangsbo J. Fatigue in soccer: a brief review. *J Sports Sci*. 2005;23:593–599. PubMed doi:10.1080/02640410400021286
2. Mohr M, Krustrup P, Andersson H, Kirkendal D, Bangsbo J. Match activities of elite women soccer players at different performance levels. *J Strength Cond Res*. 2008;22:341–349. PubMed doi:10.1519/JSC.0b013e318165fef6
3. Andersson HA, Randers MB, Heiner-Moller A, Krustrup P, Mohr M. Elite female soccer players perform more high-intensity running when playing in international games compared with domestic league games. *J Strength Cond Res*. 2010;24:912–919. PubMed doi:10.1519/JSC.0b013e3181d09f21
4. Rampinini E, Impellizzeri FM, Castagna C, Coutts AJ, Wisloff U. Technical performance during soccer matches of the Italian Serie A League: effect of fatigue and competitive level. *J Sci Med Sport*. 2009;12:227–233. PubMed doi:10.1016/j.jsams.2007.10.002

5. Di Salvo V, Gregson W, Atkinson G, Tordoff P, Drust B. Analysis of high intensity activity in Premier League soccer. *Int J Sports Med*. 2009;30:205–212. PubMed doi:10.1055/s-0028-1105950
6. Gabbett TJ, Mulvey MJ. Time–motion analysis of small-sided training games and competition in elite women soccer players. *J Strength Cond Res*. 2008;22:543–552. PubMed doi:10.1519/JSC.0b013e3181635597
7. Spencer M, Lawrence S, Rechichi C, Bishop D, Goodman C. Time-motion analysis of elite field hockey, with special reference to repeated-sprint activity. *J Sports Sci*. 2004;22:843–850. PubMed doi:10.1080/02640410410001716715
8. Austin DJ, Gabbett TJ, Jenkins DG. Repeated high-intensity exercise in a professional rugby league. *J Strength Cond Res*. 2011;25:1898–1904. PubMed doi:10.1519/JSC.0b013e3181e83a5b
9. Buchheit M, Mendez-Villanueva A, Simpson BM, Pourdon PC. Repeated-sprint sequences during youth soccer matches. *Int J Sports Med*. 2010;31:709–716. PubMed doi:10.1055/s-0030-1261897
10. D'Auria S, Gabbett T. A time–motion analysis of international women's water polo match play. *Int J Sports Physiol Perform*. 2008;3:305–319. PubMed
11. Gabbett TJ, Jenkins DG, Abernethy B. Physical demands of professional rugby league training and competition using microtechnology. *J Sci Med Sport*. 2012;15:80–86. PubMed doi:10.1016/j.jsams.2011.07.004
12. Tan F, Polglaze T, Dawson B. Activity profiles and physical demands of elite women's water polo match play. *J Sports Sci*. 2009;27:1095–1104. PubMed doi:10.1080/02640410903207416
13. Batterham AM, Hopkins WG. Making meaningful inferences about magnitudes. *Int J Sports Physiol Perform*. 2006;1:50–57. PubMed
14. Gregson W, Drust B, Atkinson G, Di Salvo V. Match-to-match variability of high-speed activities in Premier League soccer. *Int J Sports Med*. 2010;31:237–242. PubMed doi:10.1055/s-0030-1247546
15. Weston M, Drust B, Gregson W. Intensities of exercise during match-play in FA Premier League referees and players. *J Sports Sci*. 2011;29:527–532. PubMed doi:10.1080/02640414.2010.543914
16. Duffield R, Coutts AJ, Quinn J. Core temperature responses and match running performance during intermittent-sprint exercise competition in warm conditions. *J Strength Cond Res*. 2009;23:1238–1244. PubMed doi:10.1519/JSC.0b013e318194e0b1
17. Buchheit M, Haydar B, Ahmaidi S. Repeated sprints with directional changes: do angles matter? *J Sports Sci*. 2012; in press. PubMed